Development of Integrated Filtration System for Water Treatment and Wastewater Reclamation in Developing Countries

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Introduction

- Bangkok, like other mega cities in developing countries, is suffering from the shortage of water resources due to the deterioration of natural water qualities.

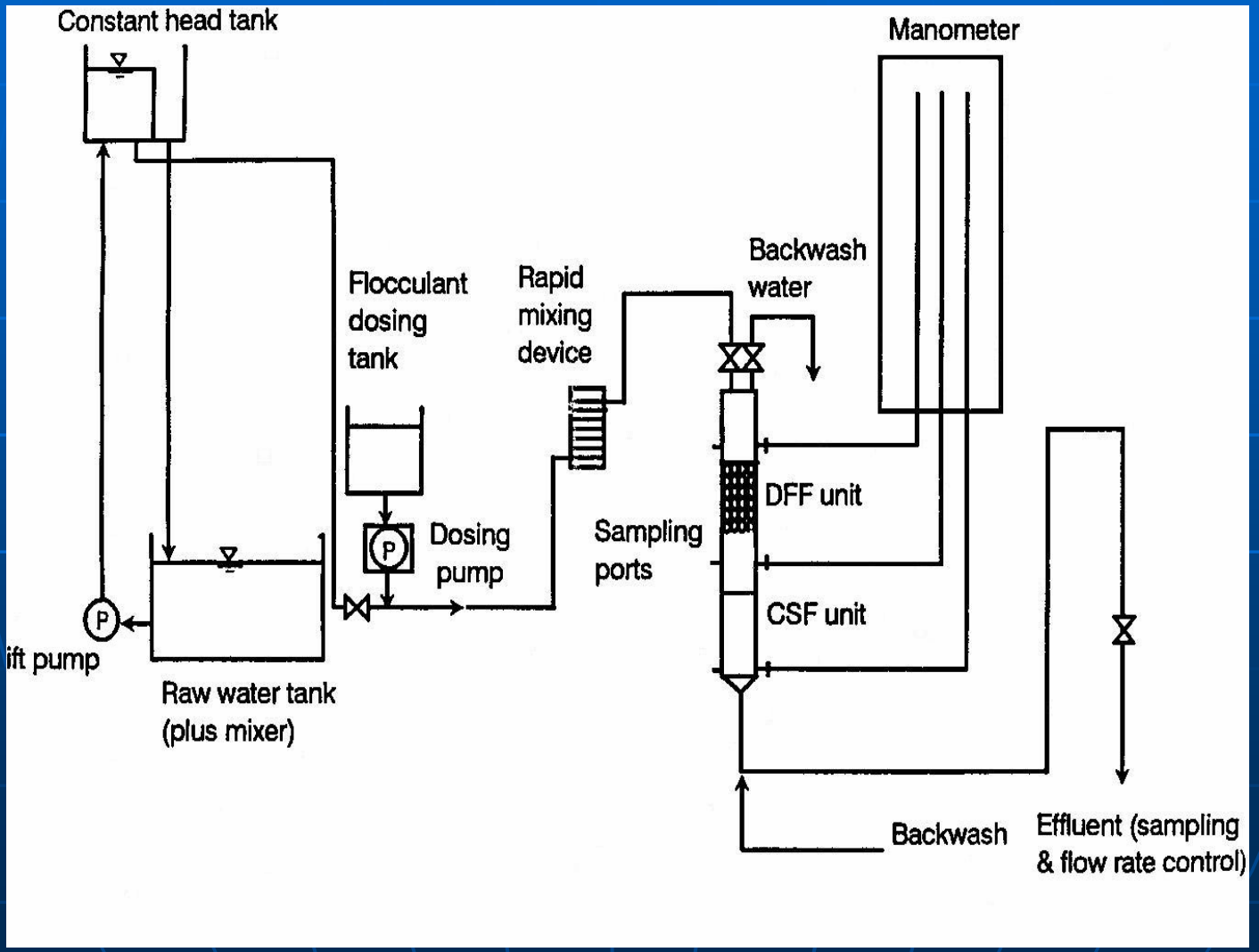
- To overcome these problems, efficient water treatment systems for producing good quality water supply and treated wastewater for reuse are needed.

- Integrated filtration system employing floating media filter coupled with conventional sand/ zeolite filter or membrane filtration was developed for water treatment and wastewater reclamation purposes.

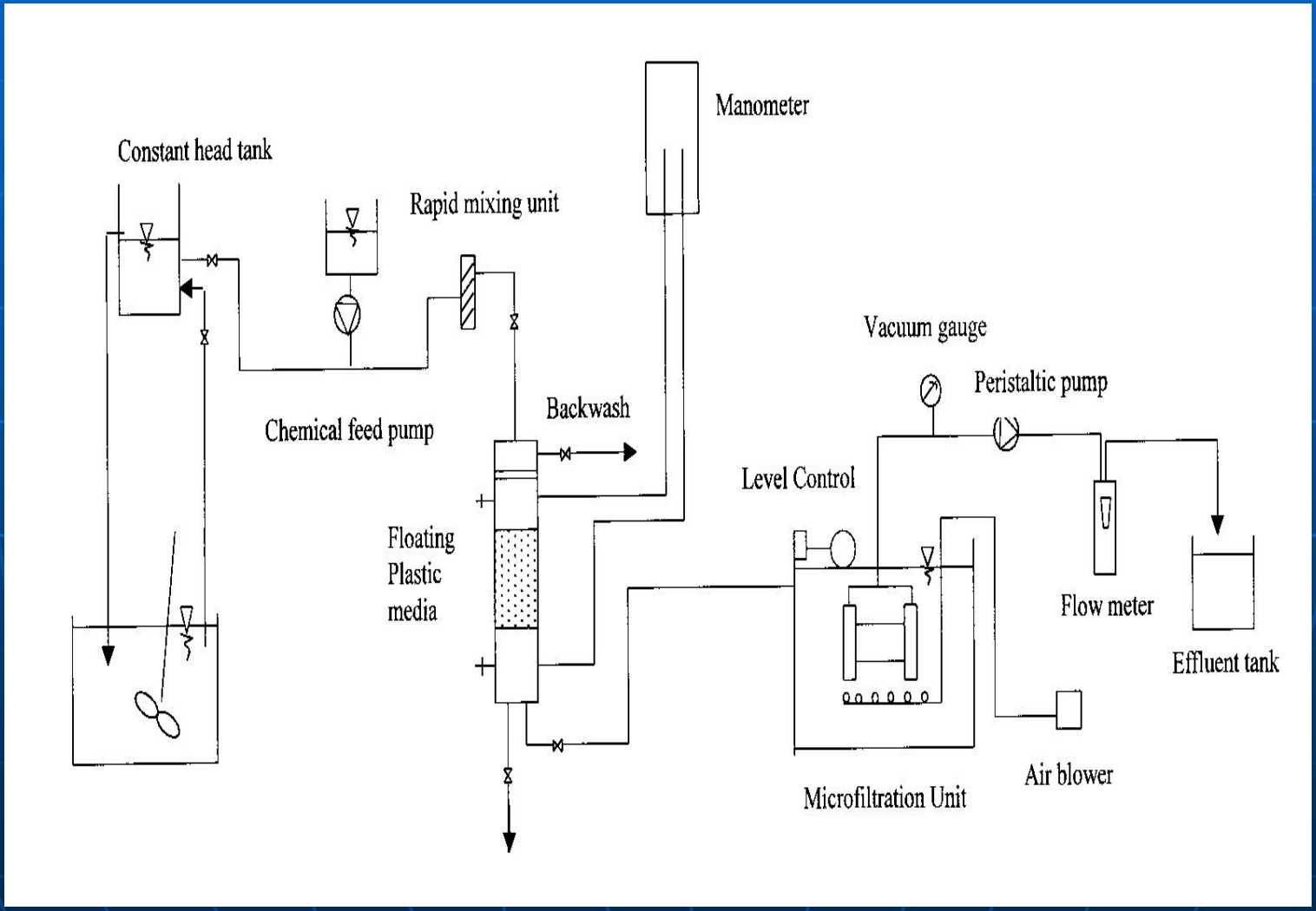
Integrated Filtration System

- Filtration is an essential unit for solid separation in conventional water treatment and tertiary wastewater treatment processes.
- Its applications include direct filtration of low turbidity water or filtration of coagulated water for high turbidity water.
- In this study, floating media filtration system coupled with coarse sand filter/ zeolite bed/ microfiltration membrane was applied to the treatment of surface water and secondary effluent.
- The advantages of system include smaller footprint comparing to conventional water treatment processes, high treatment efficiency and low operating cost.

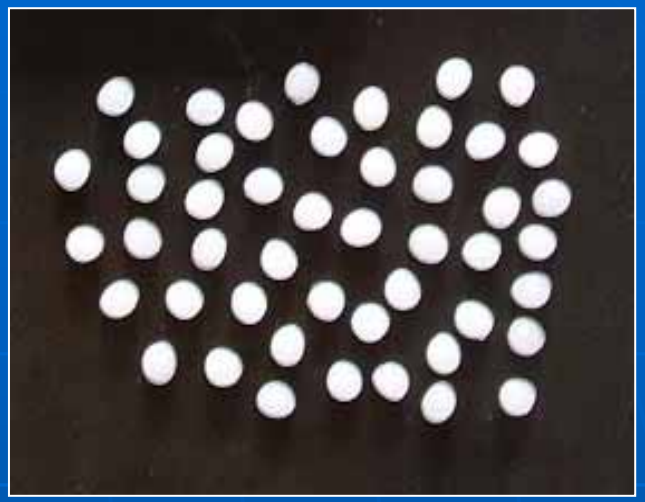
Floating media filter coupled with coarse sand filter or zeolite bed for surface water treatment and wastewater reclamation



Floating media filter coupled with microfiltration membrane for surface water treatment



Laboratory scale experimental unit



Polypropylene bead

Hollow fiber membrane module

Pilot scale testing at Bangkhen water treatment plant

Floating media filter

Microfiltration membrane unit

Research series on Integrated Filtration System

1. Floating media/coarse sand filter for surface water treatment (lab scale) - turbidity removal
2. Floating media filter coupled/zeolite bed for wastewater reclamation (lab scale) - turbidity, N, P removals
3. Floating media filter/MF membrane for surface water treatment (lab scale) - turbidity, NOM, microorganism removals
4. Floating media filter/MF membrane for surface water treatment (pilot scale) - turbidity, NOM removals

Floating media filter/coarse sand filter for surface water treatment

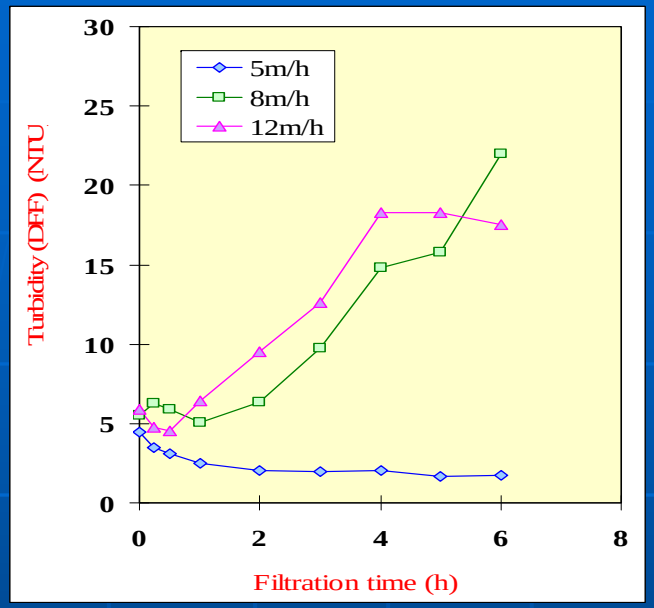
- Coagulants	Alum, $FeCl_3$, PACl, polymer
- Filtration rates	5,8,12 $m^3/m^2.h$
- Media depth	60:20, 50:30, 40:40, 30:50, 20:60 cm and 1.5 m of floating media filter alone

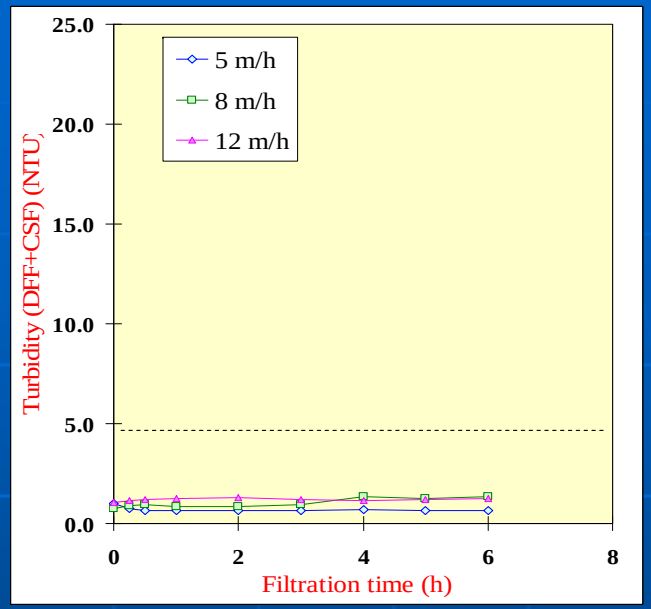
Key findings

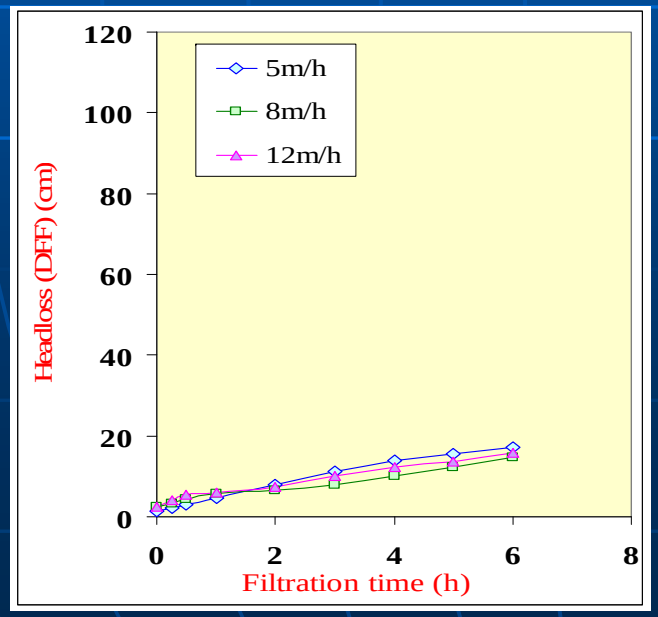
- Appropriate filtration rate of the system was found to be 5 $m^3/m^2.h$, It was limited by the particle retention capacity of floating media filter and headloss development in coarse sand filter

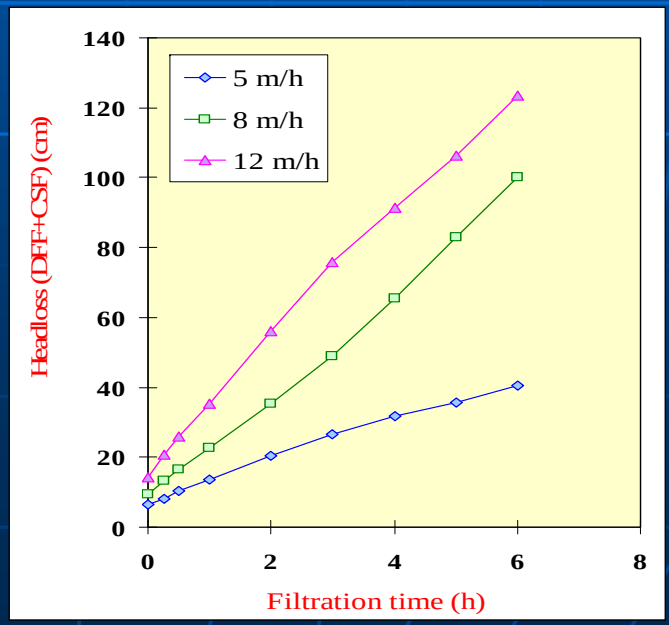
- When only floating media filter of 1.5 m was used, the filtration rate of 15 and 10 $m^3/m^2.h$ could be maintained to obtain satisfied effluent turbidity level in long term operation.

Turbidity removal and headloss development: Effect of filtration rate

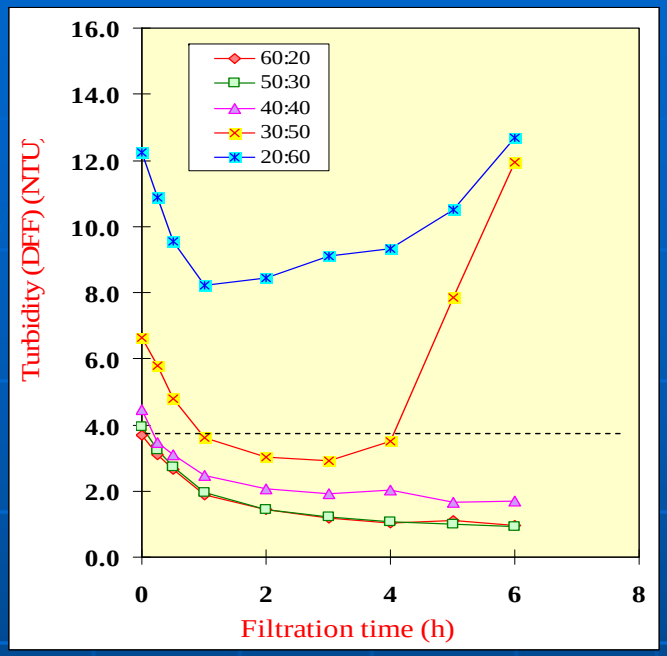


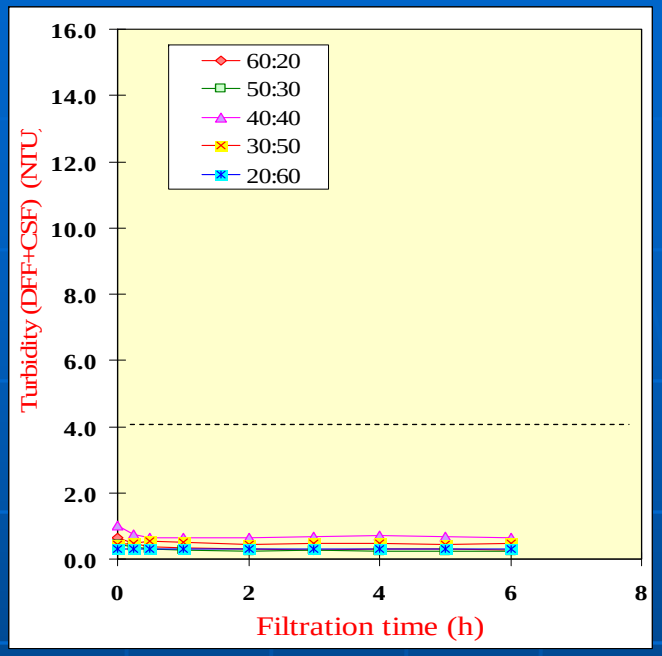


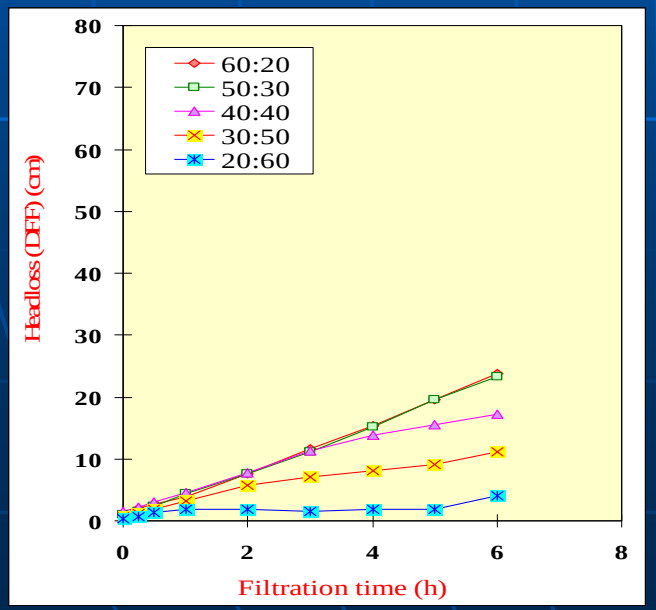


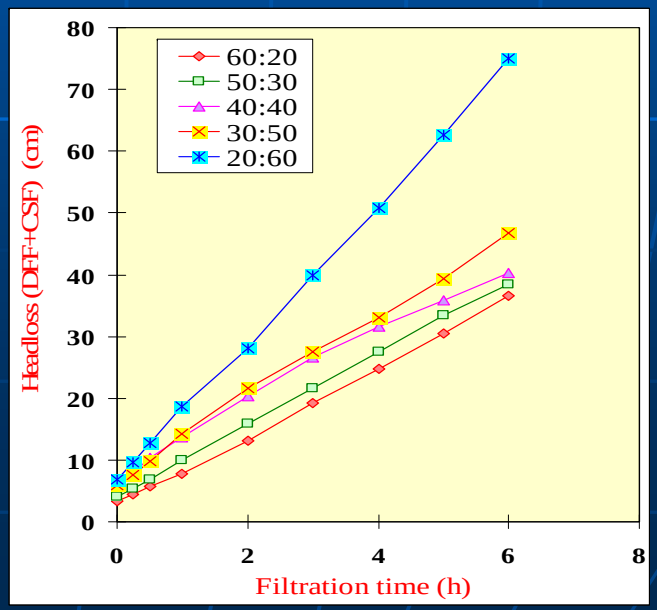


Turbidity removal and headloss development: Effect of bed depth

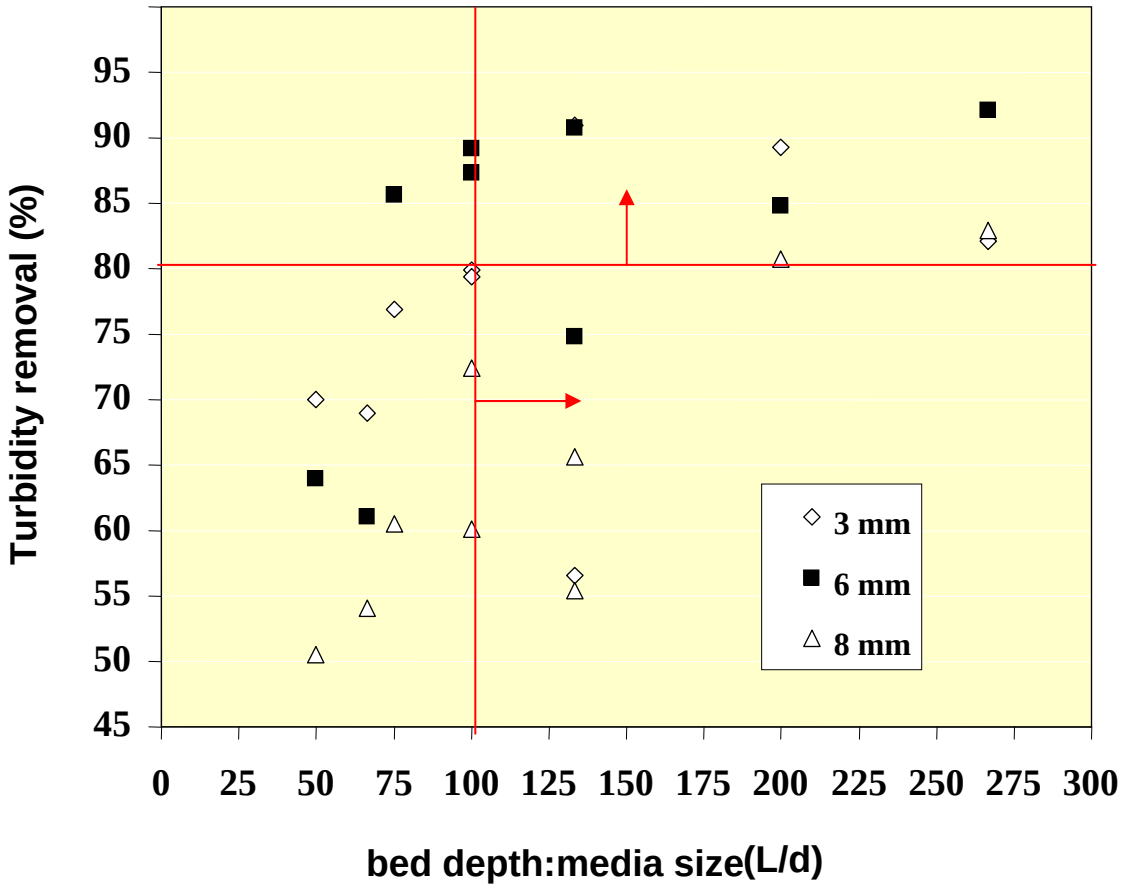








Relationship between L/d and turbidity removal in plastic media pre-filter



Floating media filter/ zeolite bed for wastewater reclamation

- Direction filtration of secondary effluent from sewage treatment plant (particle removal)
- Chemical precipitation (for P removal) using $FeCl_3$ and zeolite bed (for N removal)

- Filtration rates	1,3,5 $m^3/m^2.h$
- Media depth	40:40 cm

Key findings

- A filtration rate of 5 $m^3/m^2.h$ was proposed for direct filtration mode (only turbidity removal) whereas 1 $m^3/m^2.h$ was recommended for N, P removal from secondary effluent.

Treated water qualities for N, P removal and breakthrough period

Parameters	Std. Limit	1($m^3/m^2.h$)		3 ($m^3/m^2.h$)		5 ($m^3/m^2.h$)	
		Eff.	Hours	Eff.	Hours	Eff.	Hours
SS (mg/l)	< 5	0.4	>12	7.0	9	10.0	3
Turbidity (NTU)	< 5	0.2	>12	4.7	10	46.5	3
NH_4^+ (mg N/l)	<5	0.9	>12	5.6	9	2.1	3
PO_4^{3-} (mg P/l)	< 0.05	0.02	>12	0.13	8	1.18	3

Parameters	Influent	Effluent		% Removal
		Range	Average	
pH	7.3	5.6-6.4	6.0	
SS (mg/l)	10.3	0-2.2	0.5	91.9
Turbidity (NTU)- DFF	6.8	0.1-1.5	0.7	90.0
Turbidity (NTU)- Overall	6.8	0.1-0.9	0.3	94.6
BOD (mg/l)	18.3	0.7-1.0	0.9	95.4
NH_4^+ (mg N/l)	22.5	0-7.0	0.5	97.8
PO_4^{3-} (mg P/l)	4.41	0-0.06	0.02	99.5

Floating media filter/MF membrane for Surface water treatment

- Floating Media Filter
  - Acrylic column of 10 cm. diameter and 180 cm. long
  - Plastic media: Polypropylene (PP) bead of 3.6 mm diameter
    1 m. bed depth

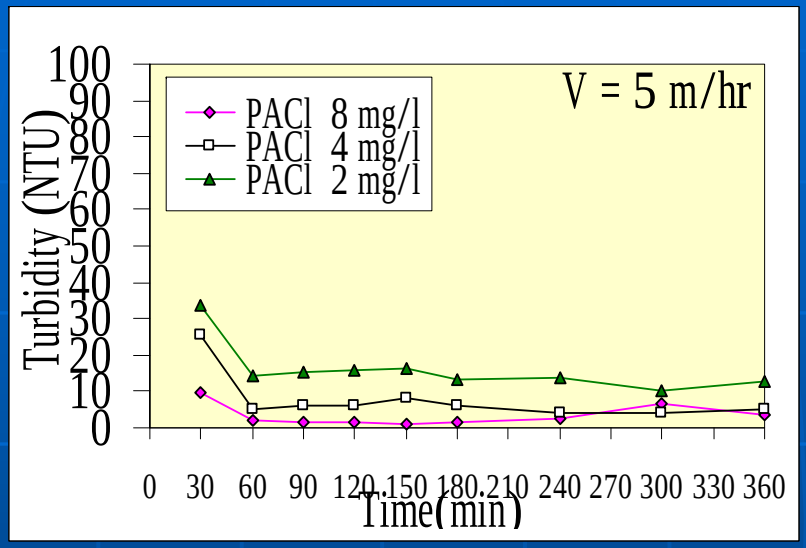
- Microfiltration Membrane Unit
  - Hollow filter membrane module with 0.1 μm pore size and 0.2 m^2 surface area

- Filtration rate — 5, 10, 15 $m^3/m^2.h$
- Coagulant — Polyaluminum chloride (PACl) at 25%, 50% and 100% of jar test

Key findings

- Floating media filter was effective in promoting flocculation and removing solid particles from raw water
- Low filtration rate (5 $m^3/m^2.h$) was preferred to prevent breakthrough and reduce the solid particle loading to MF membrane

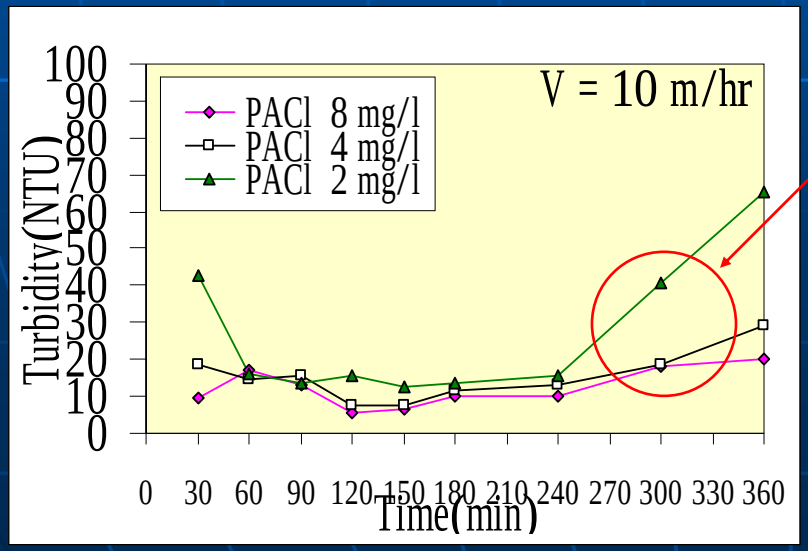
Particle removal in floating media filter (RW turbidity 80 NTU)

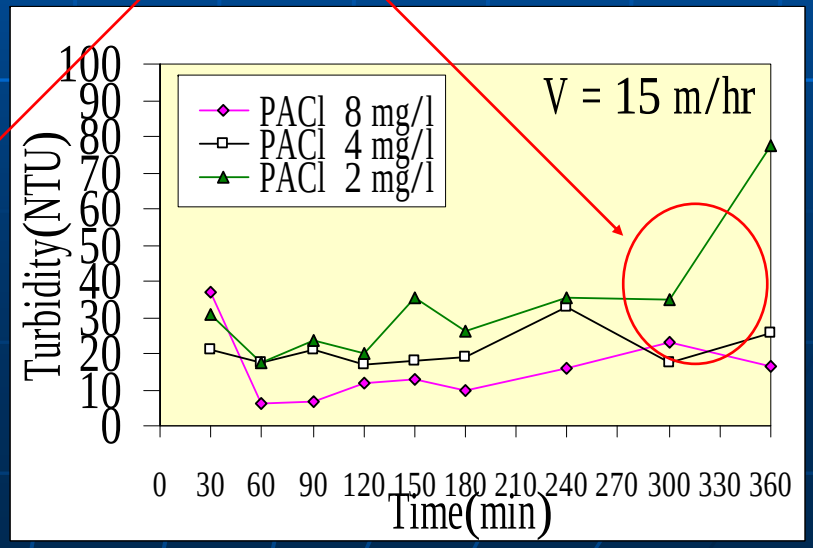


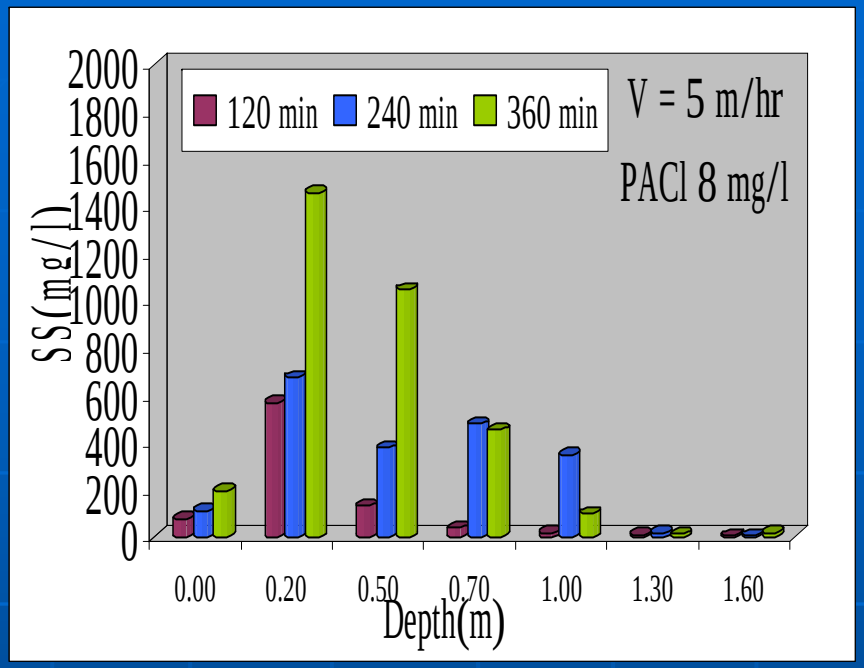
Opt. dose 100%

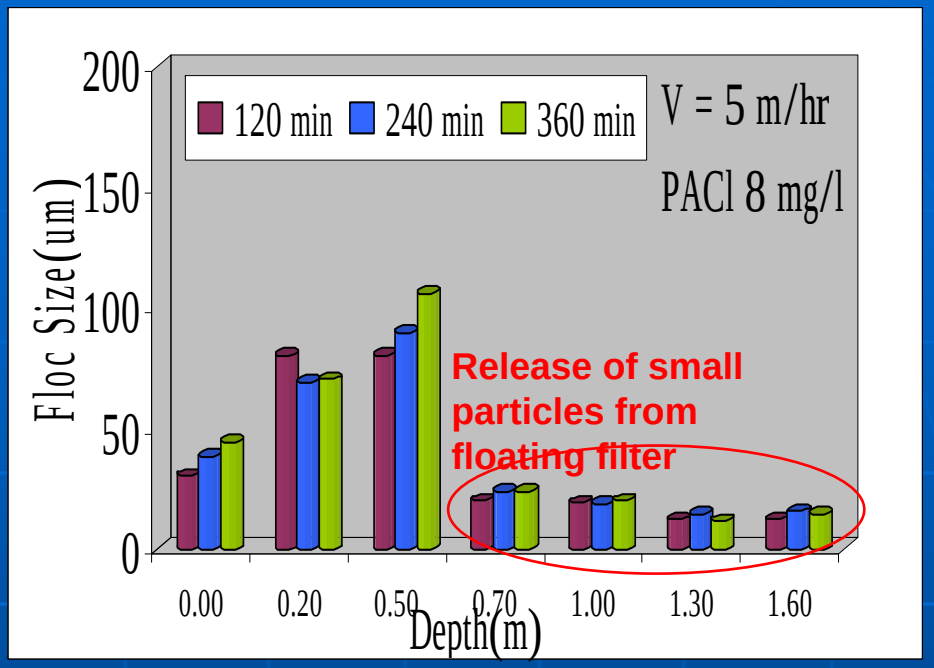
Opt. dose 50%

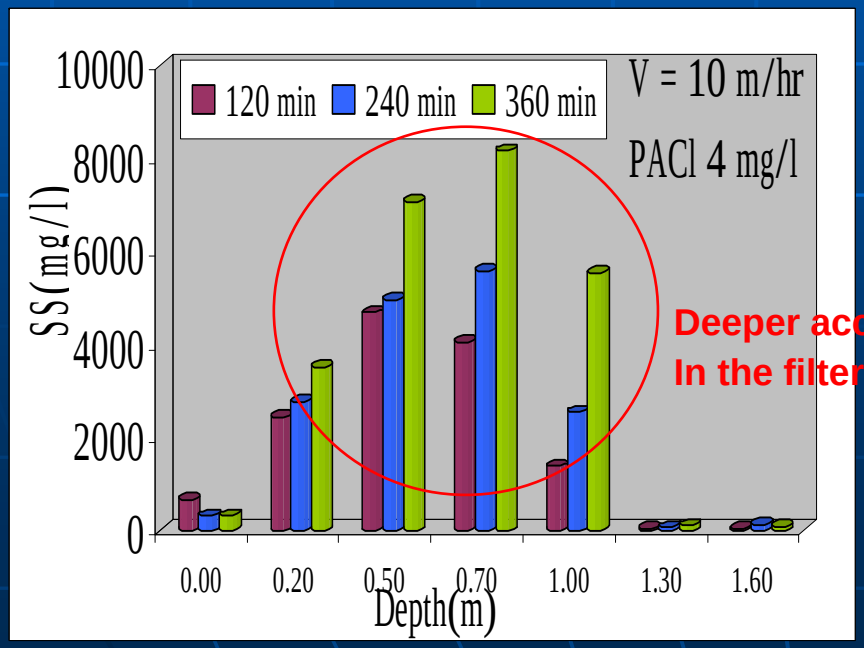
Breakthrough of particles

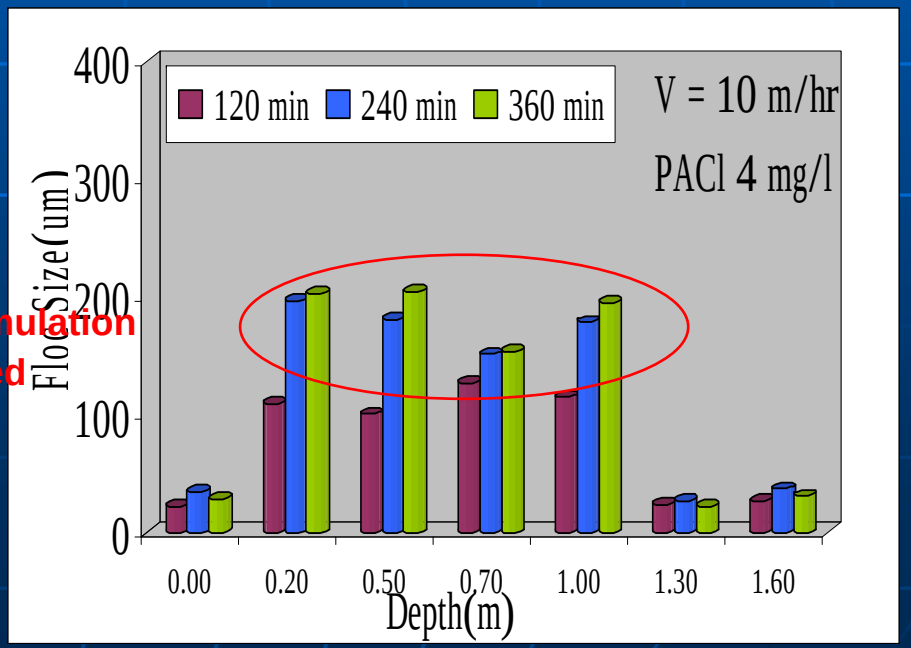




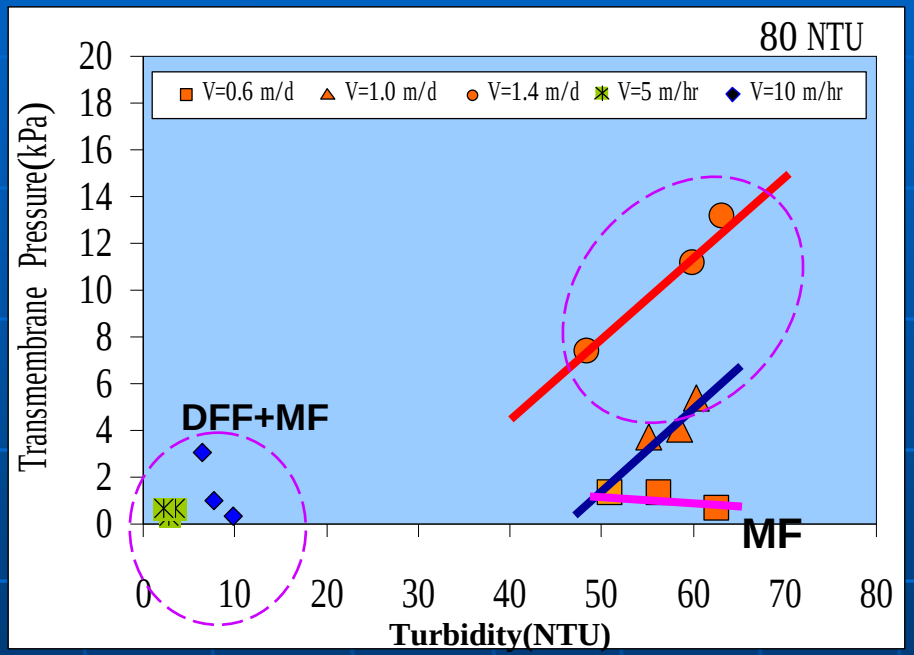

120 min
240 min
360 min
V = 5 m/hr
PACl 8 mg/l
SS(mg/l)
2000
1800
1600
1400
1200
1000
800
600
400
200
0
0.00
0.20
0.50
0.70
1.00
1.30
1.60
Depth(m)

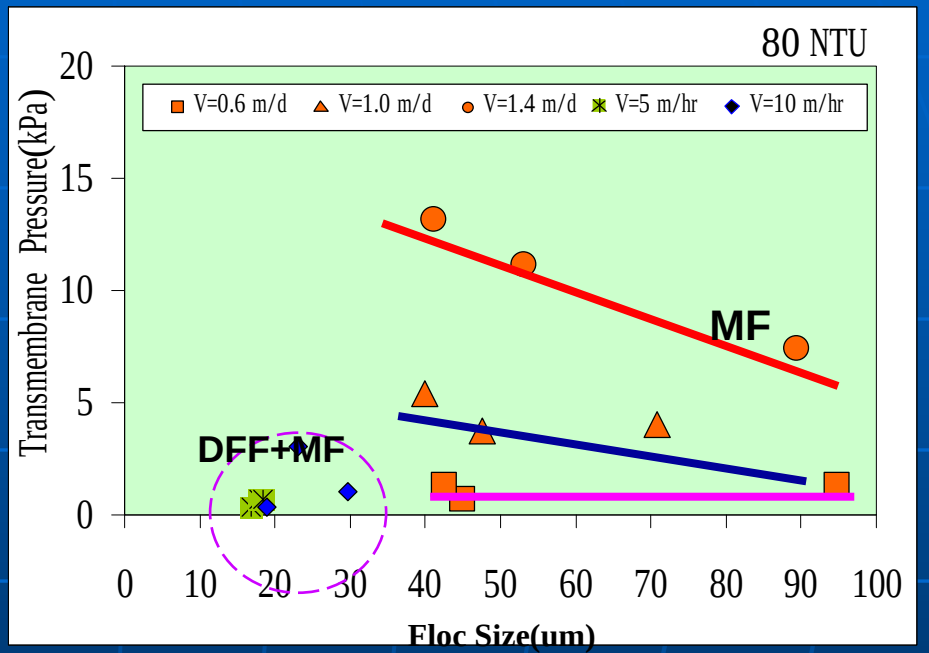

120 min
240 min
360 min
V = 5 m/hr
PACl 8 mg/l
Floc Size(um)
200
150
100
50
0
Release of small particles from floating filter
0.00
0.20
0.50
0.70
1.00
1.30
1.60
Depth(m)


120 min
240 min
360 min
V = 10 m/hr
PACl 4 mg/l
SS(mg/l)
10000
8000
6000
4000
2000
0
Deeper accumulation
In the filter bed
0.00
0.20
0.50
0.70
1.00
1.30
1.60
Depth(m)


120 min
240 min
360 min
V = 10 m/hr
PACl 4 mg/l
Floc Size(um)
400
300
200
100
0
0.00
0.20
0.50
0.70
1.00
1.30
1.60
Depth(m)

Effect of turbidity and particle size on transmembrane pressure development of MF membrane





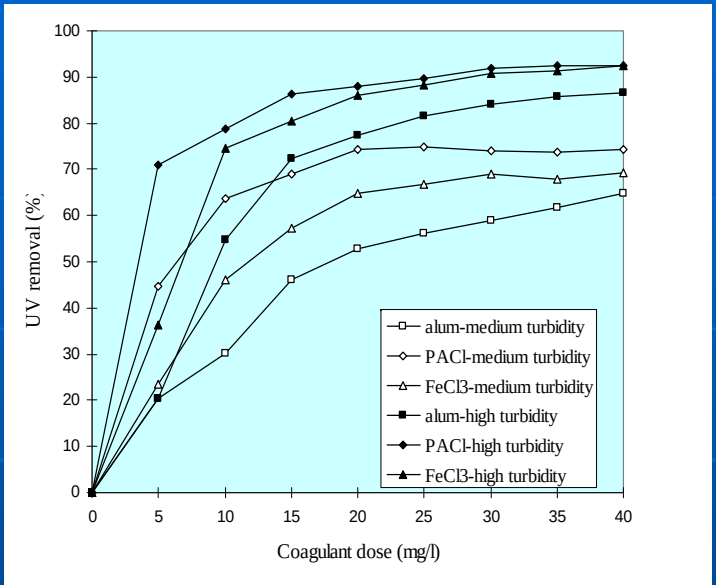
- MF membrane removed the remaining turbidity in water yielding constant effluent turbidity. Transmembrane pressure development was low following the pretreatment by floating media filter

NOM removal in floating media filter/MF system

Key findings

- High degree of NOM removal (>85%) was achieved in the system.
- Enhanced coagulation effect provided more than 80% of UV_{254} removal in floating media filter.
- NOM removal results in significant reduction in chlorine demand and THM formation.
- Both turbidity and NOM concentration affected the fouling of membrane but TMP built up was mainly caused by particulate fouling

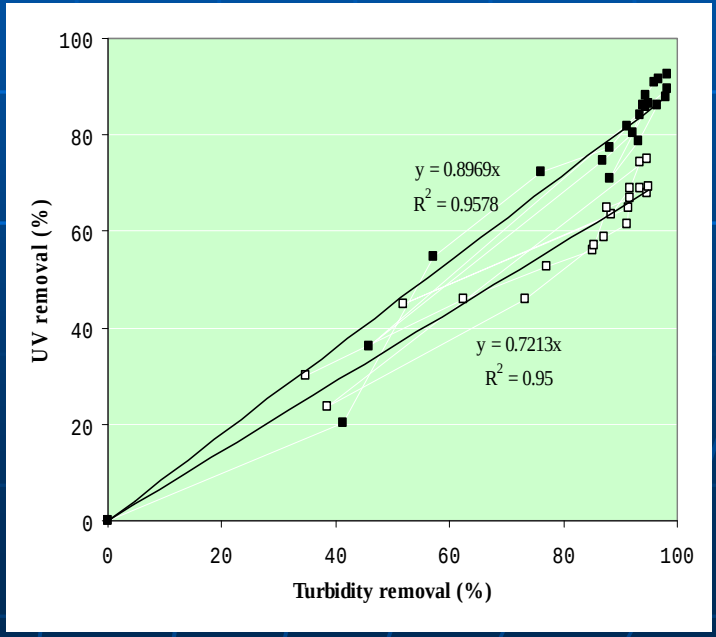
UV_{254} removal during coagulation of river water



PACl was found to be the most effective coagulant for NOM removal.

Optimum dose was 15-25 mg/l giving 75-90% UV_{254} removal.

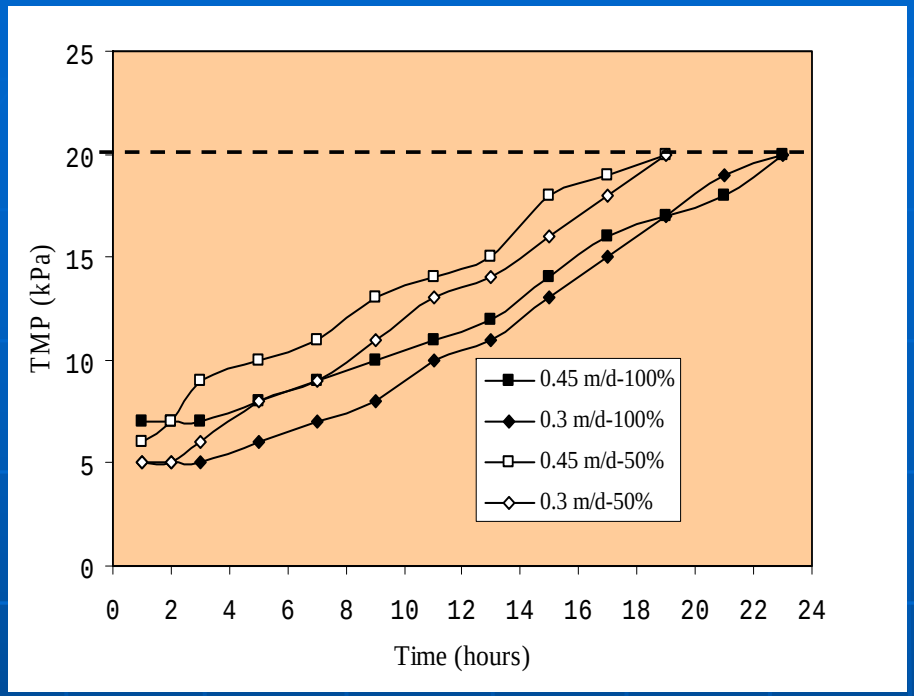
Relationship between turbidity and UV_{254} removal in floating media filter



Turbidity and NOM removal in floating media filter/MF system

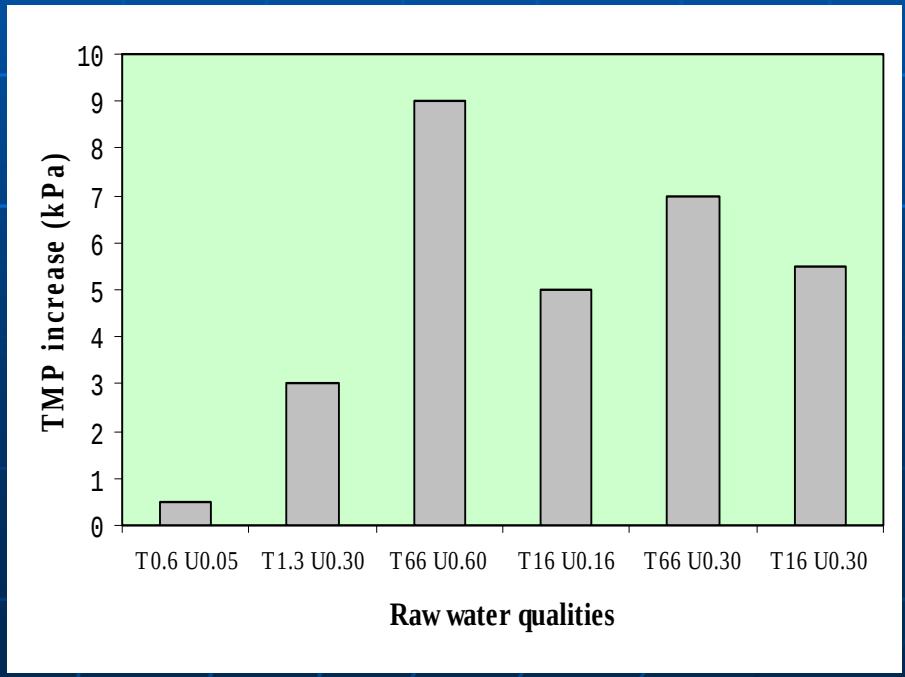
Condition	Turbidity (NTU)		UV_{254} (cm^{-1})	
	Avg.	%Removal	Avg.	%Removal
1. PACl 100%				
1.1 PP (7.5 m/h)	15.9	85.5	0.147	80.7
MF (0.3 m/d)	0.53	99.5	0.102	86.6
1.2 PP [11 m/h)	18.8	83.8	0.180	76.6
MF (0.45 m/d)	0.55	99.5	0.110	85.7
2. PACl 50%				
2.1 PP (7.5 m/h)	25.4	76.7	0.200	72.6
MF (0.3 m/d)	0.59	99.5	0.120	83.6
2.2 PP (11 m/h)	17.2	78.7	0.198	66.4
MF (0.45 m/d)	0.61	99.2	0.110	81.3

Parameters	Value	
	Range	Avg.
pH	7.65-7.84	7.73
Turbidity (NTU)	0.51-0.68	0.60
UV_{254} (cm^{-1})	0.06-0.11	0.08
DOC (mg/l)	2.78-2.99	2.88
Color (TCU)	2.8-3.6	3.2



TMP development in MF membrane unit

Effect of raw water qualities (Turbidity and UV_{254}) on TMP development



Reduction in Cl_2 demand and THM formation

0.5 to 1.0 mg/l reduction in chlorine demand was achieved after removing NOM from the water. THM formation was reduced by 40-60%

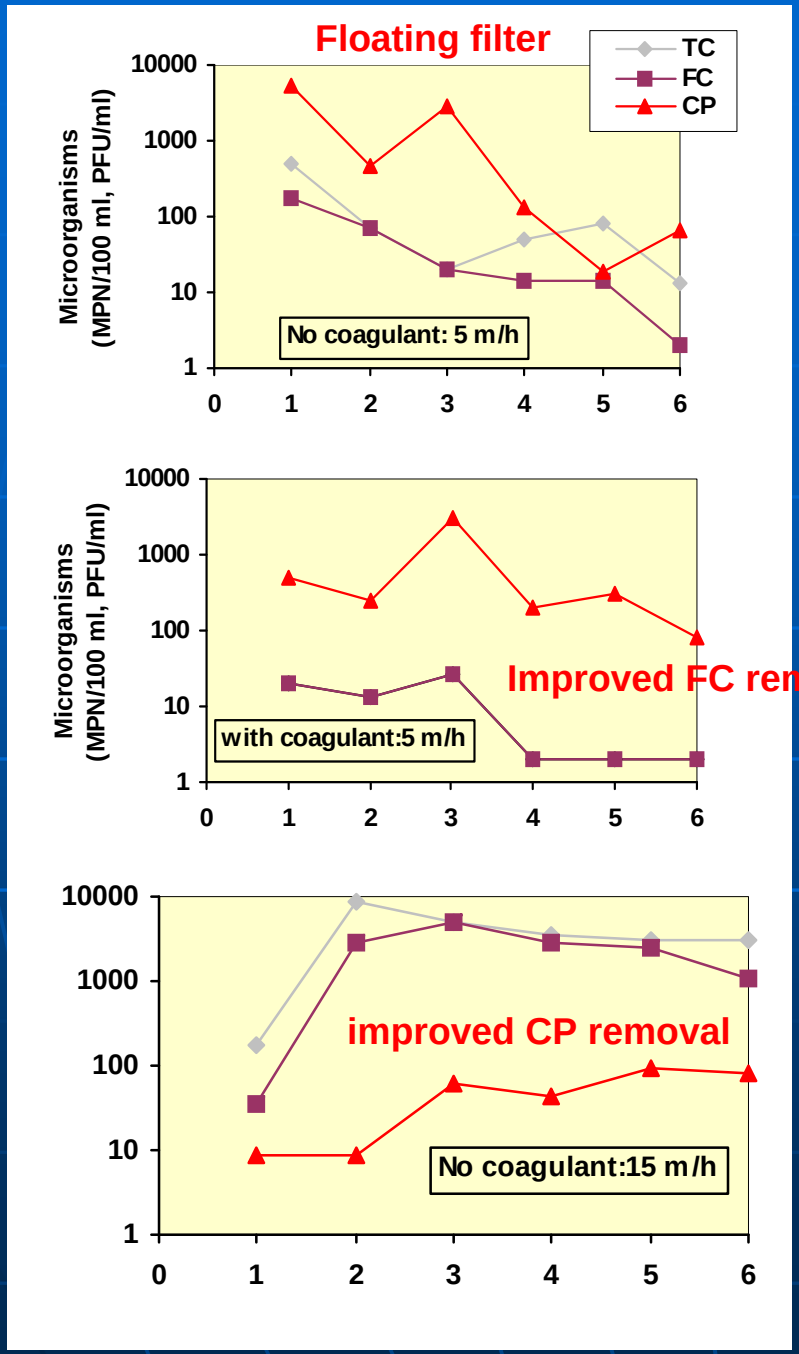
Sample	Cl_2 dose (mg/l)	CHLO (µ g/l)	DCBM (µ g/l)	DBCM (µ g/l)	Sum of THM ratio
RW	2.0	71	6	0.45	0.5
	2.5	138	9	0.44	0.8
	3.0	129	9	0.47	0.8
	3.5	145	9	0.54	0.9
	5.0	175	11	0.55	1.1
TW	2.0	33	4	0.38	0.2
	2.5	46	6	0.59	0.3
	3.0	67	8	0.70	0.5
	3.5	73	8	0.74	0.5
	5.0	86	9	0.76	0.6

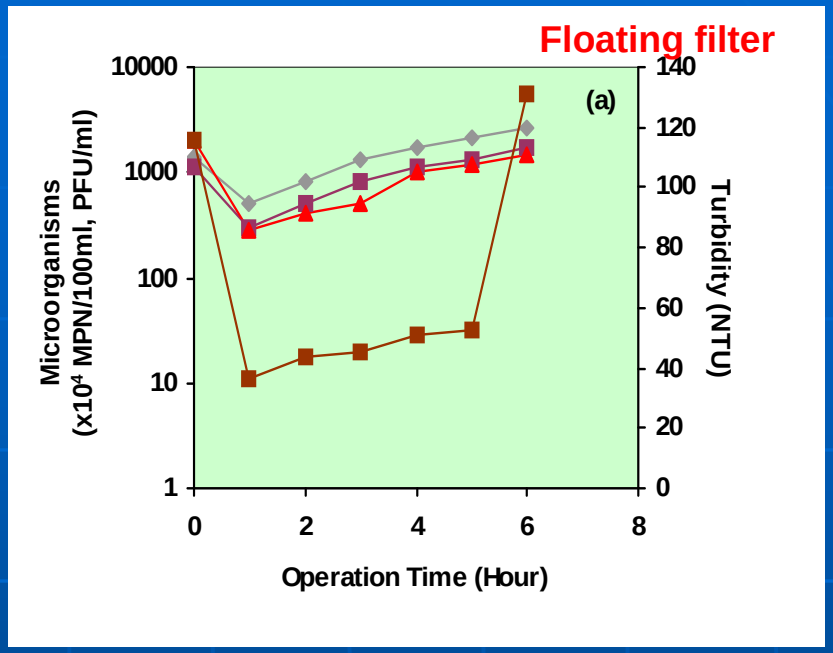
Sum of THM = $C_{CHLO}/GV_{CHLO} + C_{DCBM}/GV_{DCBM} + C_{DBCM}/GV_{DBCM} + C_{BROMO}/GV_{BROMO} < 1$
(WHO guideline)

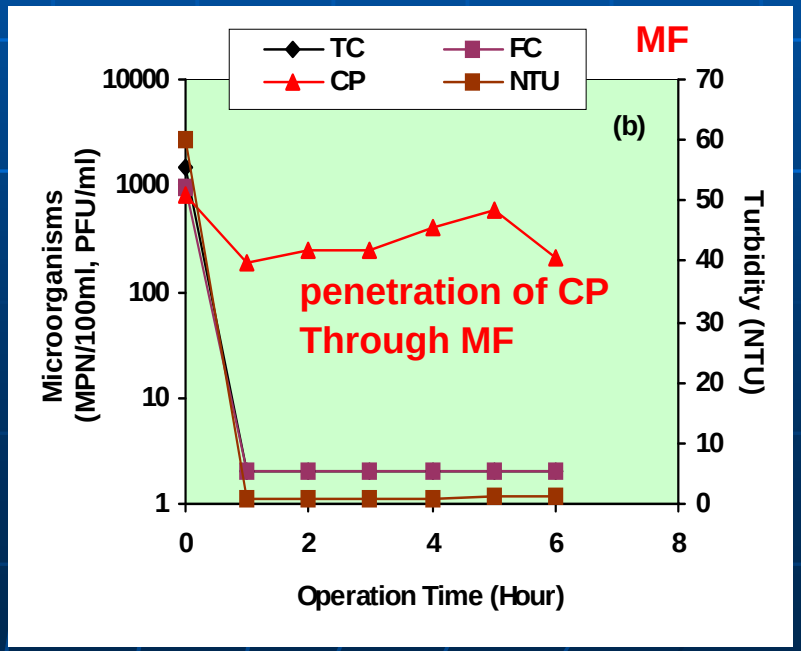
Water borne microorganism removal by floating media filter/MF membrane

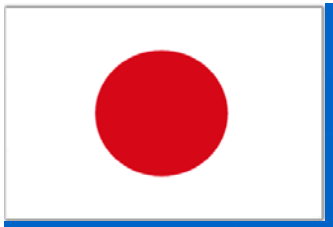
Key findings

- Freshwater algae was found partially removed by coagulation and entrapped in floating media filter but completely retained by MF membrane
- Total coliform and Fecal coliform was effectively removed by coagulation and retained in floating media filter at low filtration rate (5 m/h)
- At higher filtration rate, total and fecal coliform removal efficiencies were significantly reduced. Nevertheless, MF membrane helped removing the remaining TC and FC from water
- Coliphage was removed better in floating media filter operated at higher filtration rate but poorly retained by MF.


Floating filter
TC
FC
CP
Microorganisms (MPN/100 ml, PFU/ml)
No coagulant: 5 m/h
with coagulant:5 m/h
Improved FC removal
improved CP removal
No coagulant:15 m/h

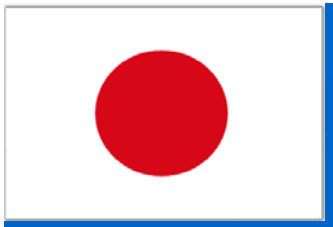

Floating filter
(a)
Microorganisms (x10⁴ MPN/100ml, PFU/ml)
Turbidity (NTU)
Operation Time (Hour)


MF
TC
FC
CP
NTU
(b)
Microorganisms (MPN/100ml, PFU/ml)
Turbidity (NTU)
penetration of CP
Through MF
Operation Time (Hour)



Future research needs & possible collaboration

- Investigation of trace pollutants (e.g. pesticide, pharmaceuticals) contamination in surface water/treated wastewater in floating media and membrane filtration system
- Enhancement of NOM removal by floating media bio-filtration or photo-oxidation associated with MF membrane for polluted water treatment
- Detailed investigation of microorganism removal in floating media filter coupled with MF membrane treating actual river water.
- Implementation of full scale integrated filtration system at Bangkok waterworks and sewage treatment plants



Other research collaborations

- Development of photosynthetic bacteria pond system for carbon recovery from industrial wastewater (with UT)
- Investigation of reverse osmosis (RO) membrane fouling during reclamation of textile wastewater (WRPC & UT)
- Application of membrane bioreactor (MBR) and RO system to solid waste leachate treatment (UT)

Full scale application of advanced leachate treatment system (1000 m^3/d) in Thailand

Thank you